US Army Two-Surgeon Teams Operating in Remote Afghanistan—An Evaluation of Split-Based Forward Surgical Team Operations

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Background: United States Army Forward Surgical Teams (FSTs) consist of twenty personnel and are the Army's smallest surgical units. Currently, they provide the majority of resuscitative surgical care for combat casualties in Afghanistan where the mission of the FST has been further extended to include "split-based operations." The effectiveness of these 10-person teams is unknown and outcome data has not been previously reported in the literature. This article evaluates the effectiveness of one split FST during a 14-month period in remote Afghanistan.

Methods: The primary endpoint was died of wounds (DOW) outcomes among United States Forces, Coalition Afghani Forces, and local national citizens. Mortality was evaluated separately for patients who received a blood transfusion. Secondary endpoints of the study included number of blood products transfused, Injury Severity Score (ISS), and mechanism of injury.

Results: Seven hundred sixty-one patients were treated and 327 patients underwent an immediate surgery. The average ISS was 12.05, and the DOW percentage was 2.36%. There were 61 patients with an ISS of greater than 24 (mortality = 23.0%), and 47 patients with an ISS of 16 to 24 (mortality = 2.13%). Nine of 121 patients transfused (7.4%) died. A total of 27 patients required massive blood transfusion and on average received 12.6 units of fresh frozen plasma and 18.2 units of packed red blood cell (ratio 1:1.49). Seven of 27 patients who received massive blood transfusion (25.9%) died.

Conclusions: Small two-surgeon surgical teams can achieve acceptable DOW rates when compared with other larger surgical units currently operating in the Global War on Terror.

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The combat environment in Afghanistan presents unique challenges for US Army medical personnel assigned to that region. The intensity of combat varies, and the mountainous terrain and changing weather conditions can make evacuation of the wounded difficult. The relatively low volume of wounded patients compared with Iraq precludes the use of multiple large combat support hospitals and the resources they require. Therefore, the United States Army Forward Surgical Team (FST) and similar small surgical units currently provide the majority of resuscitative surgical care of combat casualties at multiple isolated locations in the Afghanistan area of operations. The FST is the US Army's smallest surgical unit and is comprised of 20 personnel supporting four surgeons. It is intentionally small with limited capabilities beyond resuscitative surgery to maneuver with the location of battle. The FST is configured with two operating room (field) tables to provide a maximum of 10 operations per day and a total of 30 operations in 72 hours and can provide post-operative care for as many as eight patients for no more than 6 hours. It doctrinally carries 20 units of packed red blood cells (PRBCs). No personnel on these small teams are specifically trained to perform radiologic, laboratory, or blood transfusion therapy duties.[1,2]

Because of the lower intensity of conflict and the geographical constraints of medical evacuation in Afghanistan, the mission of the FST has been extended to include "split-based operations." This is an attempt to provide surgical and transfusion capability to isolated areas that would otherwise be considerable distances from surgical care, and requires the already small team to function as two independent entities. The effectiveness of these split teams operating well beyond their doctrinal mission is unknown, and outcome data has not been previously reported in the literature.

The purpose of this article is to evaluate the effectiveness of treatment of combat wounded by split-based FST operations using the died of wounds (DOW) percentage as the measure of effectiveness. This article evaluates 761 trauma patients treated by the 541st FST (Airborne) (Ft. Bragg, NC). The 541st FST conducted split-based operations simultaneously for 14 consecutive months at two separate locations in Afghanistan. The primary endpoint of this study is examination of DOW outcomes among three separate groups of patients: United States Forces (USF), Coalition Afghani Forces (CAF), and local national (LN) citizens. Additionally, blood product utilization and mortality among patients receiving any blood transfusion is reported.

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METHODS

An institutional review board–approved retrospective review of all admission performance improvement data of the 541st FST was conducted. This data were prospectively collected for 14 months during the team's deployment. The US Army Joint Theater Trauma Registry of the Joint Theater Trauma System (JTTS) was interrogated for all patients who died of wounds that received their initial care at the 541st FST. Demographic data including patient status, sex, and age were recorded. Physiologic variables including temperature, systolic blood pressure, respiratory rate, and Glasgow Coma Scale at the time of initial patient presentation were collected. Mechanism of injury, type of injuries, number and type of surgical procedures performed, blood product utilization, and ultimate disposition were also recorded.

The revised trauma score (RTS) was calculated for all patients. An abbreviated injury score and Injury Severity Score (ISS) were calculated for each patient using the Military abbreviated injury score 2005 (revised 2007) that received operative intervention at the FST, received a blood transfusion, or who died from wounds with or without surgery.

Patients were divided into four groups for the purposes of comparison, and each group was followed after transfer from the FST to the greatest extent allowed by available resources. USF were followed until return to duty (RTD), discharge from level V (Military Treatment Facilities in the United States), or death. CAF (including Afghani National Army and Afghani National Police), other coalition (personnel from all other countries outside of the US and Afghanistan) forces (OCF) were followed until RTD, discharge from Echelon III, or death. Local nationals (LNs) were followed until discharge from the FST, discharge from Echelon III, or death. In some instances (mostly LN), follow-up data beyond discharge from the 541st FST (Echelon II) was limited because of transfer of the patient to the local Afghan health care system. The primary endpoint was DOW outcomes. The DOW percentage is the percentage of patients who died after reaching a medical treatment facility with surgical capability among the total number of those wounded in action (WIA) who were unable to return to duty within 72 hours of injury.[3]

$$\% \text{ DOW} = \frac{\text{DOW}}{(\text{WIA} - \text{RTD})} \times 100$$

Secondary endpoints of the study include number of blood products transfused, recombinant activated factor VIIa (RF VII) usage, ISS, age, and temperature on presentation. Continuous data were analyzed using student's *t* test, and categorical data using the χ^2 test.

RESULTS

The FST conducted split-based operations simultaneously for 14 consecutive months at two separate locations in Afghanistan. During the 416-day study period, 761 patients with traumatic wounds or injuries were evaluated at the 541st FST. Nineteen patients (2.50%) presented to the FST without signs of life and were classified as killed in action. Another 66 (8.7%) patients were classified as RTD (USF, CAF, and OCF) or discharged from the FST with the supposition that they could resume their normal activities of daily living (LN). Of the remaining 677 patients, 16 died of their wounds, resulting in a DOW percentage of 2.36%. Six died at the FST

Table 1 Disposition of Patients and DOW Rates, 541st FST, November 2006–December 2007

Patient Status	Total	TR	DR	RTD	KIA	DOW at FST	DOW Post-TR	DOW Total	Dow Rate (%)*
USF	178	120	16	32	8	0	2	2	1.45
CAF	266	152	77	25	7	3	2	5	2.14
LN	297	141	139	4	4	3	6	9	3.11
OCF	20	13	2	5	0	0	0	0	0
Total	761	426	234	66	19	6	10	16	2.36

* USF vs. CAF ($p = 0.85$) and USF vs. LN ($p = 0.31$) are not significant by χ^2 test.

USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; OCF, Other Coalition Forces; TR, transferred to higher level care; DR, discharged with duty restrictions (USF, CAF, and OCF) or discharged unable to carry out most activities of daily living (LN); RTD, return to duty within 72 h (USF, CAF, and OCF) or discharged able to carry out most activities of daily living (LN); KIA, killed in action.

Table 2 Disposition of Patients and DOW Rates, 541st FST by location, November 2006–December 2007

Location	Total	TR	DR	RTD	KIA	DOW at FST	DOW Post-TR	DOW Total	Dow Rate (%)*
Spilt 1	458	250	160	24	10	4	10	14	3.30
Split 2	303	176	74	42	9	2	0	2	0.79
Total	761	426	234	66	19	6	10	16	2.36

* USF vs. CAF ($p = 0.85$) and USF vs. LN ($p = 0.31$) are not significant by χ^2 test.

USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; OCF, Other Coalition Forces; TR, transferred to higher level care; DR, discharged with duty restrictions (USF, CAF, and OCF) or discharged unable to carry out most activities of daily living (LN); RTD, return to duty within 72 h (USF, CAF, and OCF) or discharged able to carry out most activities of daily living (LN); KIA, killed in action; DOW, died of wounds.

and 10 died after transfer to higher levels of care or Afghan medical facilities (Table 1). Table 2 presents DOW breakdown by location.

Of the 761 patients treated, 327 (43.0%) patients underwent an immediate surgical operation. These 327 patients underwent a total of 581 surgical procedures. LNs and CAF patients were more likely to require an operation (Table 3). In the patient population receiving surgery, the average ISS was 12.05 ± 12.19. When USF are compared with other patients who required surgery, no difference in ISS is noted (Table 4). There were 61 patients with an ISS of greater than 24 (very severely injured) and 47 patients with an ISS of 16 to 24 (severely injured), and in these two groups of patients 15 died of their wounds (Table 5). The average ISS of a patient who died of wounds was 47.06. The most common cause of death in the combined severe and very severe injury group was head injury (n = 6) followed by exsanguination from abdominal wounds (n = 4) (Fig. 1).

There were differences in the mechanism and type of injury when USF were compared with CAF and LN patients. Of note, USF were injured more often by explosive devices

Table 3 Operative Cases by Patient Type, 541st FST, November 2006–December 2007

Patient Status	Number of Patients Requiring an Operation	Percentage of Patients Requiring an Operation
USF (n = 178)	41	23.0
CAF (n = 266)	133*	50.0
LN (n = 297)	149†	50.2
OCF (n = 20)	4	20.0
Total (n = 761)	327	43.0

* USF vs. CAF $p < 0.0001$ by χ^2 test.
† USF v. LN $p < 0.0001$ by χ^2 test.
USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; OCF, Other Coalition Forces.

Table 4 Injury Severity Score of Patients Receiving Operative Intervention at 541st FST, November 2006–December 2007

Patient Status	ISS	p vs. USF
USF (n = 41)	10.28 ± 12.00	
CAF (n = 133)	12.89 ± 12.15	0.31
LN (n = 149)	11.38 ± 11.68	0.64
OCF (n = 4)	4.50 ± 0.50	0.31
Total (n = 327)	12.05 ± 12.19	

USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; ISS, injury severity score.

Table 5 541st FST Mortality by ISS

Trauma Severity	Mortality
Mild/moderate (ISS 1–15)	1/230 (0.43%)
Severe (ISS 16–24)	1/47 (2.13%)
Very severe (ISS >24)	14/61 (23.00%)

ISS, injury severity score.

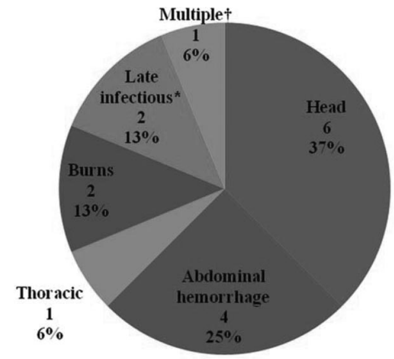

Fig. 1. *541st cause of death by mechanism of injury. *One patient with necrotizing fasciitis and one patient with pneumonia/acute respiratory distress syndrome. †Abdominal hemorrhage, hemopneumothorax, and traumatic amputation.*

compared with both CAF and LN (Table 6). Similarly, USF were more likely to suffer burn injuries compared with CAF, also due to explosive devices. CAF were more often victims of gunshot wounds or rocket propelled grenade attacks compared with USF. LN patients were more often injured through a variety of mechanisms, including motor vehicle collisions and falls when compared with USF, likely reflecting the greater percentage of nonbattle-related injuries in these patients (Table 6). Extremity injuries were most common among all groups. Both CAF and LN more often sustained abdominal and urologic injuries compared with USF (Table 7).

Age, gender, and RTS among the three groups were compared. Age and RTS are similar among the three compared groups, however, LN were more likely to be female than were USF (Table 8).

Of the 761 trauma patients evaluated at the FST during the study period, 122 (16.0%) required a blood transfusion. Total blood utilization was 1337 units (Table 9). Almost all patients transfused received PRBC (96.7%), whereas 71.3% of patients received fresh frozen plasma (FFP), and 14.8% received fresh whole blood (FWB). Nine of the 122 patients transfused (7.4%) died of their wounds (Table 10).

Among those transfused, 27 (22.7%) patients required a massive blood transfusion (MBT) defined as any patient who received 10 or more units of PRBC or the combination of 10 units of PRBC and FWB. On average, MBT patients received 9.27 ± 5.14 units of FFP, and the average number of PRBC transfused in a MBT patient was 15.15 ± 7.18 The average number of FWB units transfused in MBT situations was 3.23 ± 4.40 (Table 11). This resulted in a FFP to RBC ratio of 1:1.49 in all patients who received a MBT. In patients who received a MBT and survived the plasma, RBC ratio was 1:1.54 (Table 12). This compares to a plasma:RBC ratio of 1:2.08 in non-MBT patients (Table 13). Of note, 12 of 27 (44.4%) of massive transfusion patients received FWB. A total of 18 patients received FWB, demonstrating that 12 of 18 (66.6%) of patients receiving FWB received it in the context of a massive transfusion. Of the 27 patients who received MBT,

Table 6 Primary Mechanism of Injury of Patients Treated at 541st FST, November 2006–December 2007

Patient Status	Exp (%)	MVC (%)	GSW (%)	Fall (%)	RPG (%)	Stab (%)	Burns (%)	Helo (%)	Other (%)	Total
USF	102 (57.3)	8 (4.5)	30 (16.9)	3 (1.7)	6 (3.4)	1 (0.6)	5 (2.8)	9 (5.1)	14 (7.9)	178
CAF	113 (42.5)*	13 (4.9)	101 (38.0)*	3 (1.1)	30 (11.3)*	1 (0.4)	0 (0.0)*	0 (0.0)*	5 (1.9)*	266
LN	109 (36.7)†	37 (12.5)†	81 (27.3)†	20 (6.7)†	3 (1.0)	9 (3.0)	13 (4.4)	0 (0.0)†	25 (8.4)	297

* USF vs. CAF $p < 0.05$ by χ^2 test.
† USF vs. LN $p < 0.05$ by χ^2 test.
USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; exp, explosive devices; MVC, motor vehicle collision; GSW, gunshot wound; RGP, rocket propelled grenade; Helo, helicopter crash.

Table 7 Injuries by Type Treated at the 541st FST, November 2006–December 2007

Patient Status	ABD (%)	Ext (%)	Vasc (%)	Uro (%)	GYN (%)	Thor (%)	HN (%)	Neuro (%)	Burn (%)	Other (%)	Total
USF (n = 178)	6 (2.6)	125 (54.3)	3 (1.3)	0 (0.0)	0 (0.0)	9 (3.9)	32 (13.9)	14 (6.1)	14 (6.1)	27 (11.7)	230
CAF (n = 266)	41 (11.0)*	188 (50.5)	9 (2.4)	9 (2.4)*	0 (0.0)	15 (4.0)	58 (15.6)	30 (8.1)	5 (1.3)*	17 (4.6)*	326
LN (n = 297)	65 (15.9)†	164 (40.2)	4 (0.9)	10 (2.5)†	3 (0.7)	33 (8.1)†	68 (16.7)	23 (5.6)	18 (4.4)	20 (4.9)†	408

*U SF vs. CAF $p < 0.05$ by χ^2 test.
† USF vs. LN $p < 0.05$ by χ^2 test.
USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; ABD, abdominal; Ext, extremity; Vasc, vascular; Uro, urological; GYN, gynecologic; Thor, thoracic; HN, head and neck; Neuro, neurologic.

Table 8 Age, Sex, and Revised Trauma Score of Patients Treated a 541st FST, November 2006–December 2007

Patient Status	Age	Sex		RTS
		Male (%)	Female (%)	
USF (n = 178)	24.4 ± 5.0	177 (99.4)	1 (0.6)	7.41 ± 1.67
CAF (n = 266)	25.7 ± 6.3*	266 (100)	0 (0)	7.45 ± 1.34
LN (n = 297)	23.0 ± 14.0	271 (91.2)†	26 (8.8)†	7.49 ± 1.15
OCF (n = 20)	27.9 ± 5.4*	20 (100)	0 (0)	7.82 ± 0.06
Total (n = 761)	24.4 ± 9.9	734 (96.5)	27 (3.5)	7.47 ± 1.34

* USF vs. CAF and USF vs. OCF $p < 0.05$ by student's *t* test.
† USF vs. LN $p < 0.05$ by χ^2 test.
USF, United States Forces; CAF, Coalition Afghani Forces; LN, local national; OCF, Other Coalition Forces; RTS, revised trauma score.

Table 9 Blood Products Used by 541st FST (November 2006–December 2007)

Blood Product Type	Units Blood Products	Number of Patients Transfused (%)	Average Number Units Transfused
Packed red blood cells	785	118 (96.7%)	6.43 ± 6.02
FFP	451	87 (71.3%)	3.70 ± 4.44
Whole blood	101	18 (14.8%)	0.83 ± 2.46
Total blood products	1337	122 (100%)	10.96 ± 11.87

seven (25.9%) died of wounds (Table 10). Four died from hemorrhage. The average ISS of a MBT patient was 27.40 ± 17.97 (Table 12). Twelve patients who received MBT were given RF VIIa, and of these four died of their wounds.

DISCUSSION

The mission of the 541st FST was to provide resuscitative surgical care to American and Coalition soldiers in two separate, remote locations in Afghanistan during a period of 14 months. To accomplish its mission, the team was divided into 2 sections of 10 personnel each (Table 14). The 541st FST collectively treated 761 trauma patients in the 14-month study period. Despite being divided into two separate locations with limited capabilities, the team as a whole achieved a DOW rate of 2.36%. This compares favorably with an overall DOW rate of 4.5% in both Afghanistan and Iraq for the entire Global War on Terrorism (internal data JTTS). The 541st DOW rate also compares favorably with that of World War II (3.5%) and the Vietnam War (3.2%).[3] When the survival by ISS is compared with a similar cohort of patients treated at a combat support hospital in Iraq (where wounded are typically directly evacuated), survival probability appears to be higher at the CSH for patients with an ISS greater than 30 (Fig. 2). Unlike civilian institutions which typically report outcome in terms of how many patients per 100 survive, military medical units have traditionally reported survival data as the percent of patients per 100 who died of wounds. Specifically, the DOW percentage is the percentage of patients who died after reaching a medical treatment facility with surgical capability among the total number of those WIA who were unable to return to duty within 72 hours of injury.[3]

Table 10 Mortality Based on Transfusion Status

Patient Status	Mortality	Percentage
All transfused	9/122	7.4%*
Mass transfused	7/27	25.9%†
Transfused, excluding mass	2/94	2.1%
Transfused fresh whole blood	4/18	22.2%
No transfusion	7/639	1.1%

* $p = 0.05$ vs. no transfusion.
† $p = 0.005$ vs. no transfusion.

Table 11 Blood Product Utilization Among Mass Transfusion Patients (n = 27)

Blood Product Type	Number of Patients Transfused (%)	Average Number Units Transfused	Lowest Number Units Transfused	Highest Number Units Transfused
Packed red blood cells	27 (100%)	15.15 ± 7.18	7	28
Fresh frozen plasma	27 (100%)	9.27 ± 5.14	2	20
Whole blood	12 (44.4%)	3.23 ± 4.40	0	12
Total blood products	27 (100%)	27.65 ± 15.31	12	70

Table 12 Mass Transfusion Patient Blood Product Utilization by Survival Status (n = 27)

	ISS	Average Plasma	Average RBC	Plasma: RBC Ratio
All patients (n = 27)	27.40 ± 17.97	12.56 ± 8.9	18.19 ± 10.75	1:1.49
Survivors (n = 20)	21.65 ± 13.41	10.95 ± 7.68	16.6 ± 8.56	1:1.54
Nonsurvivors (n = 7)	43.86 ± 22.67	17.14 ± 11.11	22.71 ± 15.38	1:1.33

ISS, injury severity score; RBC, red blood cell units.

Table 13 Nonmass Transfusion Patient Blood Product Utilization by Survival Status (n = 92)

	ISS	Average Plasma	Average RBC	Plasma: RBC Ratio
All patients (n = 92)	13.03 ± 10.19	2.15 ± 2.18	4.18 ± 2.29	1:2.08
Survivors (n = 90)	12.13 ± 7.52	2.16 ± 2.19	4.20 ± 2.29	1:2.08
Nonsurvivors (n = 2)	29.00 ± 5.66	2.00 ± 2.83	4.00 ± 2.83	1:2.94

ISS, injury severity score; RBC, red blood cell units.

Table 14 541st FST Configuration for "Split-Based Operations"

Location A (n = 10)	Location B (n = 10)
General surgeon (Commander)	General surgeon (6-mo rotator)
General surgeon (6-mo rotator)	Orthopedic surgeon (6-mo rotator)
Nurse anesthetist	Nurse anesthetist (6-mo rotator)
Critical care registered nurse	Emergency medicine registered nurse
Licensed practical nurse	Operating room registered nurse
Surgical technician	Licensed practical nurse
Surgical technician	Licensed practical nurse
Medic	Surgical technician
Medic	Medic
Medic	Administration officer (officer in-charge)

The DOW rate is an effective measure of a combat surgical unit's proficiency because it is easily defined and calculated, it can be compared with other similar units from the same conflict, and data are available for comparison with past conflicts. However, the DOW percentage does not account for differences in the severity of wounds and when small numbers of patients are compared, wide ranges in the DOW percentage can result. For this reason, both ISS and RTS scores are included so that similar units can compare outcome using both DOW rates and ISSs.

Correctly determining the RTD patient is critical to correctly determining the DOW percentage. It can be difficult to define precisely the RTD patient, and because these patients are subtracted from the denominator, how they are determined can alter the DOW percentage dramatically. Holcomb et al.[3] in their article explaining the difficulties of understanding combat casualties statistics defined RTD patients as those who could return to duty within 72 hours. Any patient evacuated to a higher level military treatment facility from the FST was not considered a RTD patient. However, many patients (especially CAF and LN patients) were not evacuated through the military system although frequently they were evacuated to LN facilities. In many cases, these patients' wounds were serious enough that the assessment was they could not be classified as RTD, or in the case of LN patients return to normal activities of daily living within 72 hours. Table 15 lists the types of wounds these non-RTD patients suffered.

In this study, 23% of patients with very severe injuries (ISS >24), and 2.13% of patients with severe injuries (ISS 16–24) died of their wounds. When the very severe and severely wounded cohorts are combined, the DOW percentage is 13.89%. These results compare favorably with the results obtained by larger military surgical units and civilian trauma centers treating similar patients. Schreiber et al. compared outcomes between patients at a combat support hospital in Iraq and patients treated at the Oregon Health and Science University Level I trauma Center in Portland, OR. They found that coalition forces, noncoalition forces, and patients treated at Oregon Health and Science University had mortalities of 6.9%, 4.5%, and 6.1%, respectively. They also reported a mortality rate of 20% in patients with an ISS >24.[4] Similarly, Chambers et al.,[5] comparing the outcomes of patients treated in Iraq by a 52 personnel Marine Surgical Shock Trauma Platoon with a similar patient cohort at Los Angeles County trauma center, found that 12.7% of patients treated by the Surgical Shock Trauma Platoon with very severe or severe injuries by ISS died compared with 12.8% at Los Angeles County trauma center ($p = 0.56$). However, in the military study cited, patients who died from penetrating head wounds were not included in the data. Because the definition

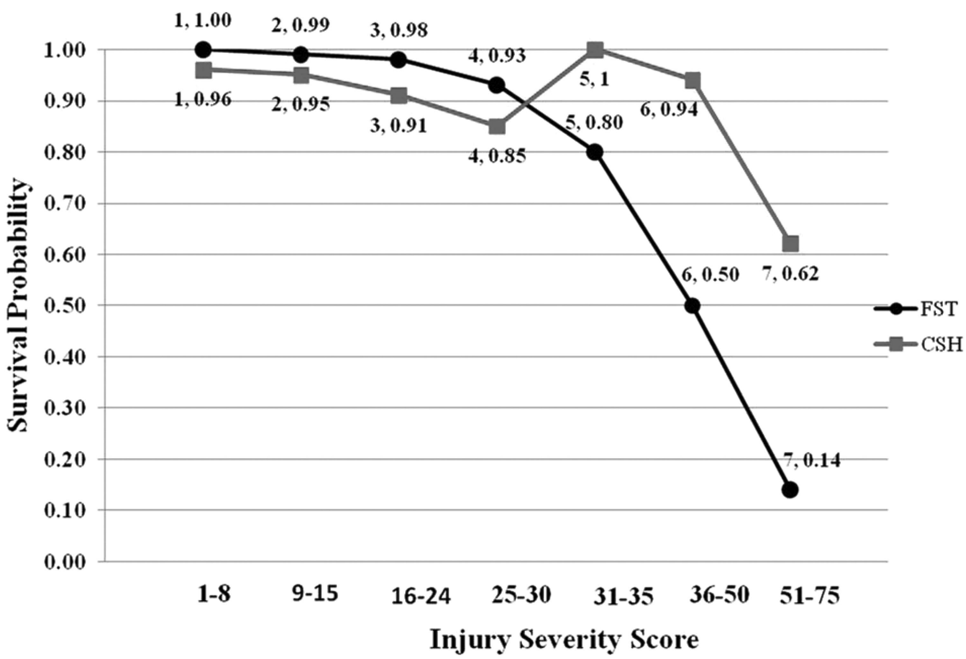

Fig. 2. *Survival probability based on Injury Severity Score 541st FST vs. Combat Support Hospital (CSH) in operation Iraqi freedom.*

Table 15 **Wounds in Patients not RTD**

Complex open wounds	54
Closed fractures or dislocation	29
Complex face or scalp laceration	27
Open fracture	26
Multiple open wounds	21
Extremity or digit amputations	15
Partial-thickness burns	14
Intra-abdominal/perineal injuries	10
Closed head injury	10
Open joint wound	8
Other*	18

* Pneumothorax, vascular, contusion, sprain.

of DOW percentage does not exclude patients who died from head wounds, these patients are included in our study even though all six patients who died from head wounds were felt to likely have nonsurvivable injuries because of massive brain parenchyma wounds, and four received nonoperative support only. If patients with brain injury as their primary mechanism of injury are excluded, the DOW percentage from the combined severe and very severe ISS group of the 541st FST drops to 10.53%. Excluding all head injuries, including blunt and penetrating mechanism (n = 46), from the calculation of the DOW percentage would decrease the DOW rate of the 541st FST from 2.36% to 1.58%.

Of concern, are the deaths by exsanguination of four patients with abdominal injuries. Two of these patients presented hours after their injuries with nonsurgical bleeding associated with coagulopathy and acidosis that did not respond to operative intervention and treatment with PRBCs, FFP, cryoprecipitate, FWB, recombinant factor VIIa (RF VIIa), and warming. Delay to surgical intervention has been reported to increase mortality in patients with intra-abdominal hemorrhage.[6] One patient who was the victim of a suicide bomber attack presented with multiple abdominal and chest injuries and required splenectomy, distal pancreatectomy, repair of a gastrotomy, left hemicolectomy, and low anterior resection (for an intraperitoneal rectal injury). During the operation, he developed hypothermia, coagulopathy, and acidosis. This patient was 1 of 17 who presented simultaneously to the FST, and after the transfusion of over 70 units of blood products (including FWB and RF VIIa), application of chitosan, correction of the hypothermia, and several attempts at repacking the abdomen, he died. The last patient died as a result of a severe liver injury in which the hepatic veins were torn from the inferior vena cava (post mortem assessment).

There is substantial evidence in the combat literature that increasing the ratio of FFP to PRBC improves survival in combat casualties.[7–10] There is also evidence that in coagulopathic patients, early platelet transfusion is also beneficial.[10,11] Recombinant factor VII has also been shown, when used early in coagulopathic combat patients, to decrease the PRBC requirement in these patients.[12] Decreasing the PRBC requirement in trauma patients is important, because the transfusion of PRBC is associated with infection, multiorgan failure, and mortality.[13–16] Conversely, transfusion of FFP and fibrinogen in particular may be independently associated with improved survival in combat patients.[9,17]

FSTs in Afghanistan have been augmented in several important ways (Table 16). Perhaps the most important of these is FFP and cryoprecipitate and the equipment to thaw these components. However, platelets are not available at the FST, and FWB transfusion is currently used at the FST when platelets are required. The military practice of FWB transfu-

Table 16 Comparison of Doctrinal and Augmented FST Operations

Doctrinal	Augmented/Split
Continuous 72 h operations	Continuous operations
20 personnel	10 personnel per location
General surgeon (3)	General surgeon 2/1 Split
Orthopedic surgeon (1)	Orthopedic surgeon 0/1 Split
2 operating room tables	1 OR table each location
Limited holding capacity	Minimal holding capability
20 Units PRBC	Augmented with FFP and cryoprecipitate
Mobile	Semipermanent improved facilities
No organic X-ray	Basic X-ray without technicians
No flouroscopy	Flouroscopy without technician
Limited bedside laboratory capability	Limited bedside laboratory capability

sion remains controversial. However, it is commonly used in the combat environment and increased survival has been reported in MBT combat patients who receive either aphoresis platelets or FWB.[18] Furthermore, the risk of transmission of infectious disease such as hepatitis C has been very low in patients who have received FWB.[19]

An aggressive approach to plasma and platelet transfusion was adopted by the 541st FST. When it was anticipated, a patient would require 4 or more units of PRBC, our procedure was to attempt to transfuse FFP and PRBC at a 1:1 ratio. If it seemed likely more than 10 units of PRBC would be required, FWB collection was started immediately, and RF VIIa was given early in the patient's course. Once the transfusion of FWB was started, its use was continued to supplement PRBC and FFP transfusion as in MBT situations these components were rapidly depleted. Type O FWB and PRBC were transfused in all cases as other blood types were not available. Type AB, and A FFP were similarly used without crossmatch. Rh negative PRBC were reserved for female patients. The infusion of crystalloids was minimized as much as possible throughout the resuscitation.

The overall mortality of patients receiving transfusion from the 541st FST was 7.4%. In patients who received massive transfusion therapy, the mortality was 25.9%. The DOW rate of patients receiving FWB was 25%. These results suggest that a very small surgical element can achieve acceptable results when performing transfusion therapy and compare favorably with those obtained in larger military hospitals and civilian institutions. Como et al.[20] studying a cohort of trauma patients who received blood transfusion treated in a large urban trauma center reported an overall mortality rate of 27% and in patients receiving MBT mortality was 39%. Interestingly, only 8% of trauma patients required blood transfusion in their study, whereas 15.9% of trauma patients treated by the 541st FST were transfused. A retrospective study that analyzed 302 patients who received transfusion at a single combat support hospital in Iraq found that 7% of patients who received less than MBT died, whereas 29% who received MBT died.[21] Perkins and coworkers reported 38% 30-day mortality in 285 patients receiving MBT using either aphoresis platelets or FWB as a source of platelets at a combat support hospital in Iraq during a 2-year period.[18] In this study, the total percentage of patients receiving blood transfusion was not reported, however 8.2% of the 8618 trauma patients admitted received MBT compared with 3% cited by Como et al. and 3.6% by the FST in this study. In a recently published experience in Operation Iraqi Freedom, 2,349 units of blood products were administered to 281 patients. Mortality for all patients receiving a transfusion was 13%. For patients receiving MBT, mortality was 19% in patients who received FWB and 26% in patients who did not receive FWB. No statistical significance was noted between MBT groups.[22]

The requirement for transfusion in the severely injured trauma patient is a consistent finding,[21,23,24] and there was, in this study, a significant difference in the ISS score of patients who underwent surgery without receiving a blood transfusion and those who underwent surgery and received blood transfusion. Four distinct patterns of injury were observed in our patients. The first were those patients who were injured and who required evacuation or continued care but not surgery or transfusion. The second group of patients had injuries that required immediate surgery, but did not require transfusion and on average these patients had an ISS of 8.81 ± 10.68. The third group of patients required blood transfusion and surgery, but they were found to have bleeding that was fairly easily controlled or that had already stopped either spontaneously or by treatment received in the field such as placement of a tourniquet. This group of patients had an average ISS of 13.03 ± 10.13, and required on average 4 units of PRBC and 2 units of FFP. The fourth group of patients had active ongoing hemorrhage that was difficult to control either because of its anatomic location or because there were multiple sources of hemorrhage. These patients had an average ISS of 27.40 ± 17.97 and typically received MBT.

The most common injuries in patients who received MBT were injuries to the abdomen and pelvis, injuries to the chest and traumatic extremity amputation. In MBT patients, 14 of 27 (52%) had injuries to at least three body regions, and 8 of 27 (30%) had injuries to at least 2 body regions. Five of 27 (19%) patients who had injuries to only one body region according to the ISS and of these, two patients had ISS scores of 75. The other three patients had lower extremity traumatic amputation injuries. The need for MBT could be anticipated in patients with abdominal or pelvic injuries with hemoperitoneum, large volume hemothorax, traumatic amputations, or in patients with multiple injuries to multiple body sites especially if hypotension or a base deficit of four or more was present. Figure 3 shows the FST approach to blood transfusion in combat casualties.

The wounds produced by the high energy weapons of war are such that the need for early transfusion must be anticipated, often before the patient arrives at the military

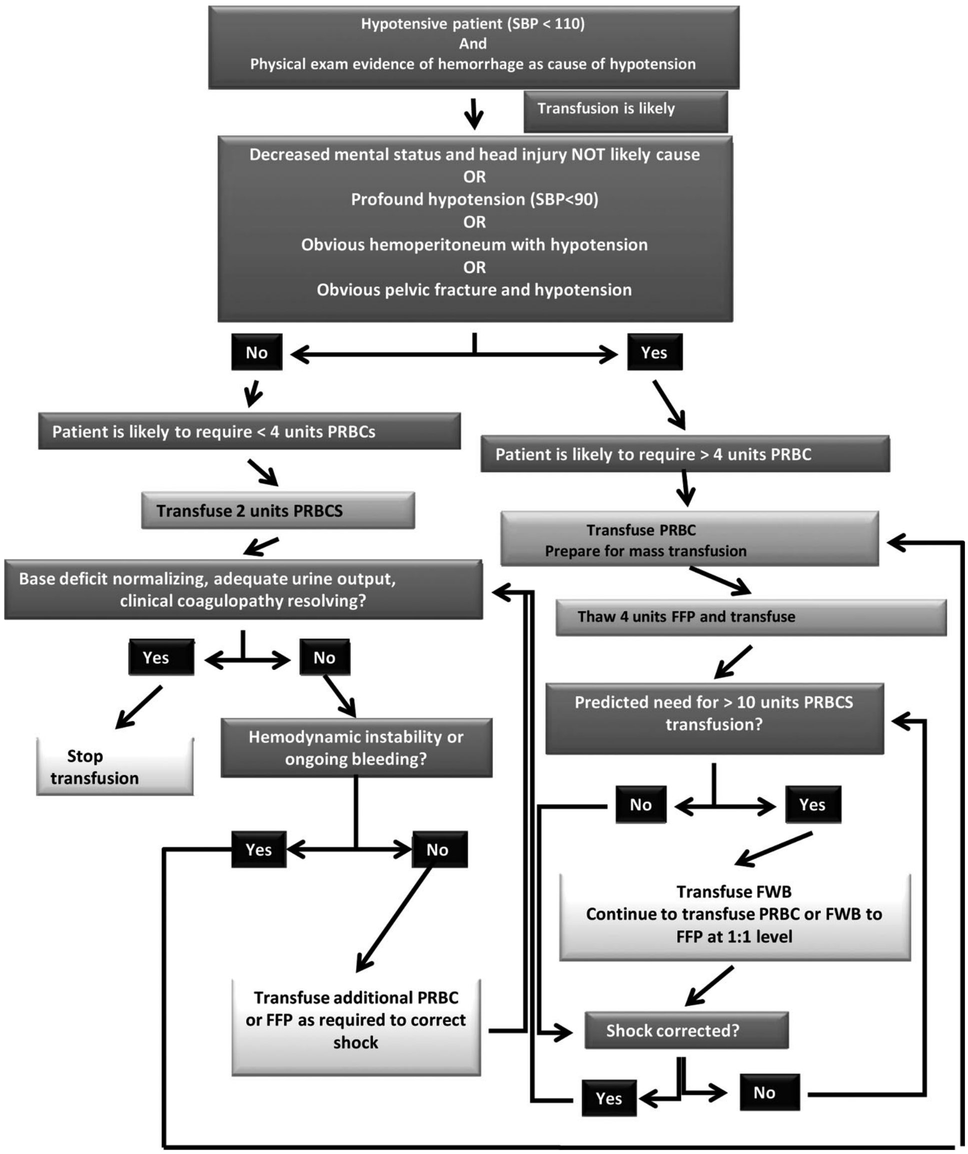

Fig. 3. *Military forward deployed blood transfusion protocol.*

treatment facility.[25] Typically, patients have multiple wounds, and the opportunity to correct hemorrhage can be fleeting before the onset of the acquired coagulopathy of trauma.[26–28] Therefore, the FST adopted an aggressive approach to resuscitation using both component therapy and FWB, similar to that of other combat surgical units.[25,29,30] The challenge of conducting a successful blood bank program with a unit comprised of 10 personnel is developing a protocol that can be easily followed, and also having the ability to anticipate quickly which patients will require blood products. Donors must be prescreened and readily available, and protocols must be in place that assures the timely availability of FWB. Posttransfusion screening for infectious disease is mandatory. There exist justifiable concerns over acute hemolytic reactions, Rh seroconversion and transfusion associated microchimerism. However, the available evidence strongly supports the aggressive use of unmatched PRBC, FFP, and FWB in patients who require MBT in the combat setting.[24,31]

An important finding of this study is that there was no difference in mortality outcomes between patients discharged from levels II and III military treatment facilities in Afghanistan (CAF, LN) and those discharged from level V military treatment facilities in the United States (USF) (Table 1). This finding strongly suggests that the effectiveness of treatment provided in the combat theater immediately after the individual suffers a combat wound is significantly related to ultimate outcome. This may seem intuitive, but combat and medical leaders should not be led to think that unstable trauma patients are being evacuated from the combat zone to level IV and level V hospitals outside the combat zone. Table 17 lists the JTTS clinical practice guidelines for evacuation from theater.

Table 17 JTTS Guidelines for Patient Evacuation

Heart rate	<120
Systolic blood pressure	>90
Hematocrit	>27
Platelet count	>50
International normalized ratio	<2.0
pH	>7.30
Base deficit	<5
Temperature	>35°C

Another interesting finding of this study is the greater probability of both CAF and LN to undergo operative intervention at the FST. The ISS among the three groups compared requiring operative intervention is similar, which argues against the initial presumption that CAF and LN patients received more operations at the FST, because they could not be transferred as easily as USF to higher levels of care. Rather, CAF and LN were more likely to require operative intervention because of the greater propensity to sustain gunshot wounds (Table 6) and wounds to the abdomen (Table 7).

The principal weakness of this study is the incomplete follow-up on all patients. Because LN and OCF were not eligible for care at US Echelon IV and V facilities, they were either cared for at the Echelon III hospitals (generally the most severely injured patients) or transferred to care within the local Afghan health care system (those less severely injured). When combat support hospital beds were not available, LN patients were transferred to local care regardless of injury severity after initial stabilization. In all cases, these patients were stable and thought to have a good, if not excellent, prognosis for survival. In some cases, patients were also transferred to hospitals operated by OCF, and follow-up data on these patients were not available. It is possible that some of the patients transferred outside of the United States care system did eventually die of their wounds, and these patients are not reflected in the study's DOW rate.

The split-based operations conducted by the 541st FST degraded the already limited capabilities of the team in several important ways. A fully equipped FST consists of three general surgeons and one orthopedic surgeon.[1] The division of the team in this case required that one location had two general surgeons, and the other location had one general surgeon and one orthopedic surgeon. It could be argued that in split-based operations, one general surgeon should be replaced with an orthopedic surgeon, placing one orthopedic surgeon and one general surgeon at each location. However, the FST was designed to have three general surgeons because its primary mission is to stabilize patients with immediately life-threatening surgical emergencies, and not to perform definitive orthopedic surgery. The orthopedic surgical procedures performed were almost exclusively simple operations such as placement of external fixation devices, fasciotomies, amputations, washout, and debridement. At the two general surgeon split location, the general surgeons performed all of these procedures. Likewise, any general surgeon who has faced exsanguinating hemorrhage without the help of an experienced assistant can understand in reality the more vexing problem was the lack of two general surgeons in each location. Ultimately, the team with two general surgeons was placed in the location with the highest volume of patients. It can be reasonably argued that when performing split-based operations, both locations should have two general surgeons as resuscitative surgery is the priority of the FST.

Nursing care was also severely impacted. The complete FST has three registered nurses including a critical care nurse, an emergency department nurse, and a surgical nurse. The FST also has three licensed practical nurses. Dividing these resources created shortages of trained personnel in the resuscitative, surgical, and postoperative management of trauma patients. Combat medics were frequently used as nurses and were required to administer drugs, manage ventilated patients, administer blood products, assist in surgical procedures, take X-rays, and process laboratory data. On occasion medics at the FST placed chest tubes and intubated patients.

Each location operated with one operating room table, three resuscitation tables, and two postoperative patient holding beds. Each location normally stored from 20 to 30 units of PRBCs, 20 to 30 units of FFP, and 30 units of cryoprecipitate. Nonstandard equipment included a plasma thawing unit, a basic X-ray machine, and at one location a Narkomed M anesthesia gas machine (Drager Medical Inc., Telford, PA). No laboratory or radiology technicians were provided, so personnel from the team trained themselves to use the equipment. Most patients arrived and were evacuated by air ambulance. At times weather and operational constraints required that the FST hold patients for prolonged periods but this was the exception. On 43 occasions more than 5 patients presented to one or the other location of the FST either simultaneously or near simultaneously. On these 43 days, 317 patients of the total 761 were treated (41.7%).

Despite the limitations and difficulties the 541st FST faced, it was remarkably successful. It would be reasonable to assume that a small surgical team would not be as effective as a larger combat support hospital. This has certainly been shown to be the case in the United States where outcomes of trauma patients treated at smaller hospitals are compared with patients treated at large trauma centers.[32–35] The FST, however, is not a small hospital, and the battlefield is dramatically different from the urban streets of the United States. The FST has a specific, focused mission, and it is trained and designed for that trauma mission. Several key personnel assigned to the team before its deployment were already experienced in battlefield trauma care. The FST commander (a board certified general surgeon), a nurse anesthetist, the detachment sergeants, and the critical care nurse all had previous experience in combat medical care. These key personnel were assigned to the team at least 1 year before the planned deployment, and developed an extensive predeployment curriculum that included among other things a rotation at the Army Trauma

Training Center at the Ryder Trauma Center in Miami, FL. The surgeons and anesthetist that rotated through the team served for 6 months, which allowed them to become proficient in trauma management. One surgeon, the commander, was present for the entire 15 month deployment, which provided continuity throughout the deployment. All members understood their roles, and these personnel were selected for this mission because of their previous demonstrated excellence.

The team defined its goals before the deployment, and that was to achieve a DOW percentage less than 3.2% (the historic DOW rate for previous recent conflicts). Each casualty event was scrutinized and early in the deployment after action reviews were performed to identify areas for improvement. The clinical staff studied the current literature and changed some practices based on recent battlefield data including the approach to blood transfusion therapy.

However, successful the 541st FST was it is important to note that the volume of patients seen by the FST was low, and the average injury severity was moderate. Medical planners must understand the ability of a normal FST to hold patients is extremely limited, and because of the shortage of appropriate nursing personnel with split-based operations, the divided sections of the FST simply cannot manage critically ill patients and continue to receive wounded. The data presented here only suggest that a very small surgical unit, when appropriately trained, staffed, and equipped, can achieve acceptable DOW results when the relative volume of patients is low, rapid evacuation is available, and the injury severity is similar to that reported here. It is likely that the ability to store and transfuse FFP and cryoprecipitate and to rapidly obtain and transfuse FWB also impacts survival. Interestingly, there was no observed statistical difference in mortality noted between patients discharged from level III military treatment facilities in Afghanistan and those discharged from level V military treatment facilities in the United States. This suggests that in the immediate period after an individual is wounded in combat, survival is directly related to the surgical care available in the combat zone for all patient cohorts considered including personnel of the United States Armed Forces.

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